

Investigation of Parametric Acoustic Response of a Fluctuating Ocean

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Award #: N00014-98-1-0079

LONG-TERM GOALS

The long-term goals are: 1) to take advantage of the ever-changing ocean environment's effects in order to provide a more complete understanding of long-range acoustic pulse propagation, 2) understanding the extent of fundamental limitations on ray-based acoustic tomography; of particular interest is the breakdown range of semiclassical methods, and 3) to address important basic physics issues that arise in the ocean problem, but within a more general context.

OBJECTIVES

There are two primary scientific objectives of this work: 1) to begin developing a geometric acoustics theory that addresses parametrically varying ocean environments in the presence of ray chaos, determines what information survives under such conditions, and determines how to extract it, and 2) to determine the sensitivity of acoustic wavefields to relevant ocean environment parameters thereby connecting the scale of changes in the ocean to range scales of wavefield correlation decay.

APPROACH

We consider acoustic propagation problems that allow for parabolic equation description. Advantage is taken of new semiclassical approaches to approximate time-evolving wavefields in systems possessing classically chaotic analogs. The methods rely on wave packets, heteroclinic orbit summations, and have been shown to be remarkably accurate in spite of relying on highly unstable chaotic trajectories. The approach is similar in spirit to the van Vleck approximate propagator, and the Gutzwiller trace formula. From this starting point, we consider systems whose governing equations can be expressed as varying with respect to a parameter; this can model, for example, a time-changing internal wave configuration. To study response and sensitivity, it is fruitful to apply perturbation theory to describe the changes arising in ensembles of classical trajectories underlying the wavefields. We compare semiclassical predictions with 'exact' numerical wavefield calculations.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 30 SEP 1999		2. REPORT TYPE		3. DATES COVERED 00-00-1999 to 00-00-1999	
4. TITLE AND SUBTITLE Investigation of Parametric Acoustic Response of a Fluctuating Ocean				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Washington State University, Department of Physics, Pullman, WA, 99164				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 3	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

WORK COMPLETED

The work completed this year falls into two projects, one in collaboration with M. Wolfson, and the other with a visiting scientist, A. Lakshminarayanan, and a WSU Ph. D. graduate student, Nicholas Cerruti. Dr. Wolfson and I are nearing completion of a paper on the stability of rays propagating through mesoscale structure in the ocean. The model is simplified, possessing a single scale of weak random structure, involves only the horizontal plane, and is isotropic. Nevertheless, it has some key features of rays propagating in random media similar to ocean acoustic rays. It has the advantage that Wolfson and Tappert have worked out some previous analytic results helpful for our current study. Preliminary results were presented at the ASA Berlin meeting. The second project was an investigation of how chaotic wave systems respond to changing a parameter in their governing equations. We used abstract maps as dynamical models, but we have in mind eventually making connections to changing mesoscale and internal wave field fluctuations. This work was published in Phys. Rev. E this year.

RESULTS

Dr. Wolfson and I have found that the stability of rays discussed above fluctuate as log normal random variables. Our results also predict the scaling of the width of the distribution, how it collapses in the infinite range limit, and gives us a prediction for the number of remaining nearly stable or intermittent rays as a function of the range. The same stability measures appear in ray theories for the amplitudes of various contributions to the wave fields. The remaining stable rays may be important for helping tomographic techniques where mostly chaotic rays exist, and the log normal distribution may have ramifications for the wave field statistics at finite range. In the second project, we found that correlation decay functions based on ensembles of rays in the chaotic maps we were considering could be analytically linked to the strength of response of the corresponding wave equation solutions.

IMPACT/APPLICATION

The work is aimed at understanding the predictability and/or other limitations of ray methods in the presence of unstable dynamics. In addition, parametric variation, once understood, is often found to be one of the only successful ways of deducing otherwise difficult-to-asertain information about complex systems such as the ocean environment. It may lead to new ocean acoustic tomography techniques.

TRANSITIONS

It is too early to discuss how these results will eventually be used by others.

RELATED PROJECTS

Additional work currently underway, but not described in this report, involves collaborations with the following individuals: M. Wolfson (WSU) and M. Brown (RSMAS-AMP).

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